

Bulk and surface Characterization of Phosphor-Doped PDMS

Victor Gardner, CRESH student, White Station High School

Mentor: Dr. Firouzeh Sabri, Ph.D. Department of Physics, University of Memphis, Memphis, TN

THE UNIVERSITY OF
MEMPHIS

Background and Introduction

Polydimethylsiloxane (PDMS)

- is a versatile silicone based polymer with a variety of applications, such as a tactile sensor in robots [1], or in biomedical applications [2].
- It is non-toxic, non-reactive, elastic, biocompatible, and hydrophobic [3].

Phospholuminescence

- Some phosphors exhibit luminescent properties when stimulated. This is phospholuminescence.
- For this study, the triboluminescent (luminescing from mechanical force) phosphor ZnS:Mn and the thermoluminescent (luminescing from heat) phosphor La₂O₂S:Eu were used.
- ZnS:Mn is one of the brightest and more impact-resilient triboluminescent phosphors [4].
- La₂O₂S:Eu is highly sensitive to temperature. This makes it useful for potential sensory application, as explored in [5].

Introduction

- The goal of this project was to characterize the bulk and surface properties of altered PDMS.
- Some PDMS samples were doped with either ZnS:Mn or La₂O₂S:Eu by 5% weight, 15% weight, or 50% weight.
- Other samples were spin-coated with the phosphor La₂O₂S:Eu.
- More samples were kept undoped and uncoated as control groups throughout the study.

Materials Synthesis and Preparation

PDMS Synthesis

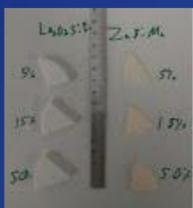


Figure 1: Doped PDMS Samples
Undoped, 5% weight phosphor, 15% weight phosphor, and 50% weight phosphor samples were mixed, degassed, and cured at 100°C for 1 h.

Spin Coating



Figure 2: Spin-Coated PDMS (1500 RPM)



Figure 3: Spin-Coater

- Undoped PDMS samples were spin-coated with a solution of 10ml IPA and ~1g La₂O₂S:Eu.
- The samples were spun at 500 RPM, 1000RPM, and 1500 RPM. Only the 1500 RPM samples were selected for further testing.
- The coated samples were placed in a vacuum chamber to dry off excess IPA, leaving only a phosphor coating.

Characterization Methods

1. Tensile Testing



Figure 4: Tensile Tester



Figure 5: PDMS Dog-Bone

- The PDMS samples were cut into dog-bone shapes
- They were subjected to strain at a rate of 45 mm/min
- The results were tabulated on a stress-strain curve.
- Young's modulus was found by isolating the linear portion of the graph.

2. Contact Angle



Figure 6: Contact Angle Measurement

- A 10 uL drop of water was deposited on each sample.
- An image was taken, and the contact angle was found.

3. Surface Potential



Figure 7: Kelvin Probe in a Faraday Cage

- The undoped and doped samples were bathed in IPA, and then placed in a vacuum to dry.
- The surface potential of 9 equal sections was measured on each sample.

4. Spectrophotometry



Figure 8: Spectrophotometer

- The samples underwent spectrophotometric analysis to analyze the interactions between phosphor and PDMS.

5. Peel Test



Figure 9: Imaging Microscope

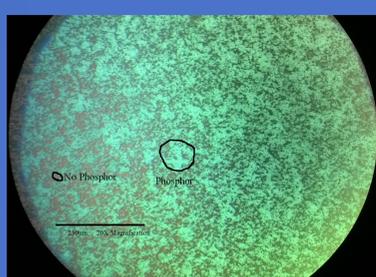


Figure 10: Optical Image of Phosphor Coating on PDMS

- After spin coating, an image was taken of the sample.
- Scotch tape was then used to peel off a layer of phosphor.
- An image was taken after the peel test, and the images were compared.

Results

a. Bulk Properties

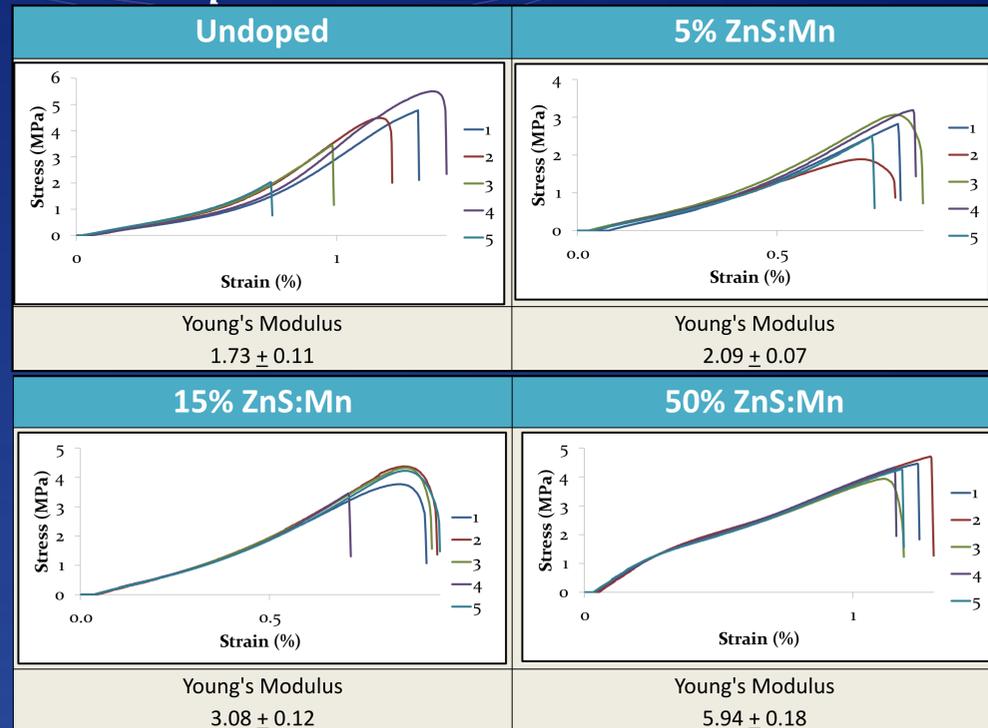


Figure 11: Measure of Elasticity

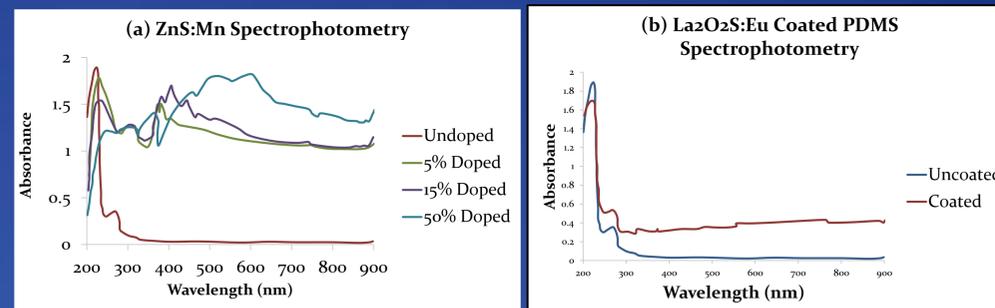


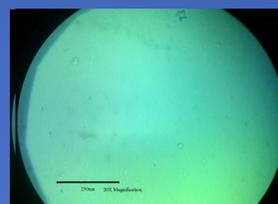
Figure 12: Spectrophotometry

b. Surface Properties

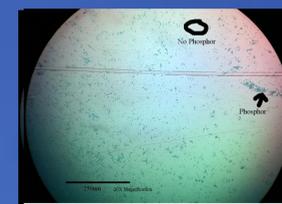
Table 1: Surface Potential and Hydrophobicity/ Hydrophilicity Behavior

Sample	Potential Difference (Volts)	Contact Angle (Degrees)
Undoped	-56.00 ± 0.11	113.5 ± 2.0 [2]
Coated La ₂ O ₂ S:Eu	-56.54 ± 0.08	138.6 ± 5.6
Doped 5% La ₂ O ₂ S:Eu	-55.45 ± 0.10	115.1 ± 3.6
Doped 15% La ₂ O ₂ S:Eu	-55.38 ± 0.04	112.4 ± 1.1
Doped 50% La ₂ O ₂ S:Eu	-55.18 ± 0.04	113.1 ± 2.1
Doped 5% ZnS:Mn	-55.41 ± 0.04	115.0 ± 0.8
Doped 15% ZnS:Mn	-55.45 ± 0.05	113.5 ± 1.0
Doped 50% ZnS:Mn	-55.60 ± 0.00	114.3 ± 0.4

(a) Uncoated (control)



(b) Before



(c) After

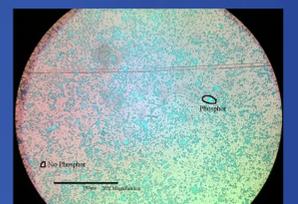


Figure 13: Peel Test

Conclusions, Discussion, Future Work

- PDMS retains its overall properties when doped with phosphor.
- It becomes less elastic and consistently more hydrophobic with increased dopant concentration.
- When coated with phosphor, the surface becomes markedly more hydrophobic.
- Because the altered PDMS retains its properties while providing a conveyance for luminescent phosphors, it has the potential to be a non-contact thermo- or mechano-sensor with reversible behavior.
- Future work will focus on more uniform coatings and coverage, as well as surface functionalization to achieve better adhesion.
- Future work will also assess the luminescence behavior of both bulk doped and surface coated samples

References

- [1] Lee, H.-K., Chang, S.-I., & Yoon, E. (2006). A Flexible Polymer Tactile Sensor: Fabrication and Modular Expansion for Large Area Deployment. *Journal of Microelectromechanical Systems*, 1681-1686. [2] Mata, A., Fleischman, A. J., & Roy, S. (2005). Characterization of Polydimethylsiloxane (PDMS) Properties for Biomedical Micro/Nanosystems. *Biomedical Microdevices*, 281-293. [3] Lätters, J. C. (1997). The mechanical properties of the rubber elastic polymer polydimethylsiloxane for sensor applications. *Journal of Micromechanics and Microengineering*, 145-147. [4] Fontenot, R. S. (2012). Comparison of the triboluminescent properties for europium tetrakis and ZnS:Mn. *Journal of Theoretical and Applied Physics*, 6-15. [5] Sabri, F. (2014). Sensing with Phosphor-doped PDMS. *IIS Conference*. London, UK.

Acknowledgments

I would like to thank Dr. Sabri for letting me work in her lab for the duration of the CRESH program. I would also like to thank Thien-Chuong Phung and Kyle Lynch for showing me how to use the lab.